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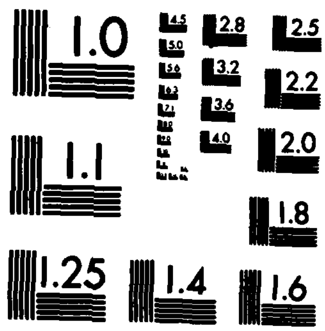

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NWC TP 6566

AD-A146 617

Visibility Monitoring in the Southern California Desert for the Department of Defense: Research on Operations-Limiting Visual Extinction

RESOLVE Protocol
Second Update

by
D. Blumenthal
Sonoma Technology
and
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for the
Public Works Department

SEPTEMBER 1984

NAVAL WEAPONS CENTER
CHINA LAKE, CA 93555-6001

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Naval Weapons Center

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

FOREWORD

The study described in this report was supported by the Joint Policy and Planning Board (JPPB) of the Department of Defense (DOD) with funds derived from participating agencies. The study is part of a continuing effort to study the decrease in visibility in the R2508 airspace and its effect on flight and test operations. This report is the first in a series of reports on this study.

Because of the continuing nature of the research, refinements and modifications may later be made in this study.

Approved by
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12 September 1984

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(U) *Visibility Monitoring in the Southern California Desert for the Department of Defense: Research on Operations-Limiting Visual Extinction*, by D. Blumenthal, Sonoma Technology, and J. Trijonis, Santa Fe Research. China Lake, Calif., Naval Weapons Center, September 1984. 34 pp. (NWC TP 6566, publication UNCLASSIFIED.)

(U) A decrease in visibility in the R2508 airspace (in the western Mojave Desert in southern California) since the mid-1940s, when flight test and training facilities were established in this region, is adversely affecting flight and test operations. The Joint Policy and Planning Board (JPPB) of the Department of Defense has initiated studies and discussions of the visibility issue with the goal of developing a management strategy to maintain and optimize the operational capabilities of the test facilities.

~~(U)~~ To identify trends in and sources of visibility degradation in the desert, JPPB initiated two programs: (1) a compilation and review of the historical visibility and air quality data in the California desert region, to be coordinated by the California Desert Air Working Group (CDAWG) and funded by CDAWG participants; and (2) "RESearch on Operations-Limiting Visual Extinction (RESOLVE), which involves measuring the visibility at key receptor sites (monitoring stations) in the R2508 region. The report describes the current status of and future plans for the RESOLVE program.

CONTENTS

1. INTRODUCTION

Historically, the western Mojave Desert in southern California has enjoyed excellent visibility and dependably good weather. In addition, the availability of large areas of relatively unused land and airspace make it ideal for aircraft-related research and development and for testing and training activities. Recognizing this, the Department of Defense (DOD) has located a number of flight test and training facilities in this region, which is designated the R2508 airspace (shown in Figure 1). These include Edwards and George Air Force Bases (AFB); the Naval Weapons Center (NWC), China Lake; and the Army National Training Center, Fort Irwin. In addition, the National Aeronautics and Space Administration (NASA) Dryden Flight Research Facility and the Army Aviation Engineering Flight Activity are located at Edwards AFB. These facilities employ a total of approximately 30,000 people, with a budget of nearly 1 billion dollars a year.

Since the mid-1940s when these facilities were established, there has been a decrease in visibility in the R2508 airspace. This decrease has adversely affected flight and test operations and has in some cases forced changes in operational procedures. On occasion, visibility degradation has been severe enough to adversely affect the optical data gathered for specific tests. At present, visibility conditions are still generally adequate for the types of test activities conducted at these facilities. However, considerable concern exists in the flight test community regarding potential adverse effects on operations due to further declines in visibility.

In order to plan for future operations at these test facilities, the Joint Policy and Planning Board (JPPB) of DOD has initiated studies and discussions of the visibility issue. The goal of the JPPB is

- To develop a management strategy to maintain and optimize the operational capabilities of the test facilities.

As a first step toward achieving this goal, the JPPB has sought input from air agencies (federal, state, and local), private industry, and other interested agencies and parties. From these inputs, several major issues have been identified that should be addressed in order to meet the goals:

1. What are the operational and economic impacts and implications of both the existing visibility impairment in the R2508 region and of potential increases in visibility degradation? Can operational procedures be developed that make optimum use of high visibility days or that are less sensitive to visibility degradation?

2. What are the current and historical trends in and sources of visibility degradation in the R2508 region?

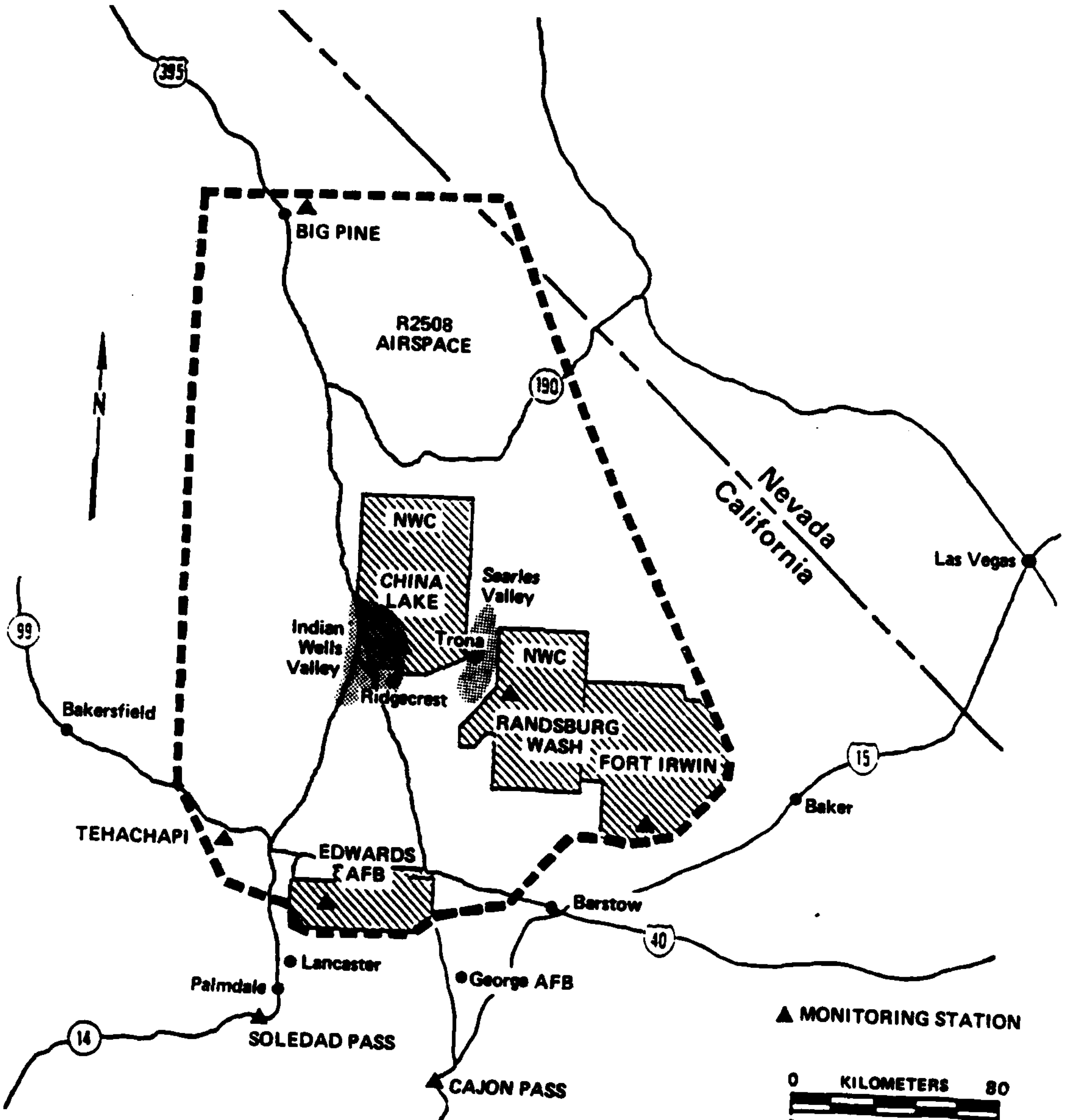

FIGURE 1. RESOLVE Monitoring Stations.

3. What are the probable effects on visibility of changes in emissions in upwind air basins or of increased urbanization and industrialization of the desert?

4. How will visibility in the desert be affected by current or proposed regulations? Are current regulations adequate to protect visibility in the R2508 region?

In addressing these issues, the JPPB will cooperate with and obtain input from government agencies and interested parties. Some studies will be funded directly by JPPB; but whenever possible, JPPB will cooperate with and make use of studies funded by other parties to obtain necessary information.

DOD managers are concerned that further degradation of visibility will have an adverse effect on operations. The operational and economic impacts of visibility impairment (Issue 1) are being evaluated by the DOD community. The JPPB has decided to conduct some of this evaluation in-house because the test and optical data collection expertise is unique to military test activities and because of complications arising from the classified nature of many of the tests. NWC has assigned a Navy employee full time to the task of documenting the visibility requirements of DOD operations and determining the operational impacts and costs incurred by DOD caused by the hampering or cancelling of tests because of impaired visibility. In addition NWC has issued a contract to quantify the slant path extinction requirements for various types of DOD tests and to determine the correlation of slant path extinction with the surface measurements made during the program titled "RESearch on Operations-Limiting Visual Extinction" (RESOLVE). The protocols for these investigations will be made available to the public for comment upon request, and the results will be available for review by all interested parties.

To identify the trends in and sources of visibility degradation in the desert (Issue 2), the JPPB has initiated two programs. First, the JPPB has contributed funds to a compilation and review of the historical visibility and air quality data in the California Desert region. This study is to be coordinated by the California Desert Air Working Group (CDAWG) and is funded by CDAWG participants. Second, JPPB has initiated the program RESOLVE. This program involves measurement of the visibility at key receptor sites in the R2508 region and measurement of those parameters that affect visibility at both the receptor sites and at likely upwind source sites. The data obtained will be analyzed to determine the baseline visibility in the R2508 region and to quantify the contribution to visibility impairment of various sources and source regions. The study will help provide a basis for the analysis of the impact of regulatory actions on visibility.

The subsequent sections of this report describe the current status of and future plans for the RESOLVE program. A letter from the Commander of NWC at China Lake that requested program design suggestions was mailed to interested parties on 13 December 1982. A public meeting was held on 27-28 April 1983 at the Environmental Protection Agency (EPA) Region IX office to present and review a draft program plan and to obtain additional input. The responses to the 13 December letter and the comments from the public meeting have been carefully considered and used in preparing this program plan. The monitoring program has been initiated, but not all aspects of the measurement and analysis plans have been finalized. Comments and suggestions regarding this document are welcome, and input from interested parties will continue to be sought at regular intervals throughout the RESOLVE program.

Although RESOLVE should help determine the current contributions to visibility impairment in the region, a detailed understanding of the effects on visibility of changes in

pollutant emissions distribution or amount (Issue 3) will require the development of models. Although statistical relationships will be developed during RESOLVE, the development and validation of regional grid models is somewhat dependent on the results of RESOLVE and have not yet been addressed by the JPPB. Likewise, the effects of present and future regulations on visibility (Issue 4) have not yet been addressed by the JPPB. However, the Western Oil and Gas Association (WOGA) has awarded a contract to Sierra Research to investigate the effects of present and future regulations on visibility. The first phase of this study is an evaluation of emission inventories in air basins that may contribute visibility degrading components to the R2508 region. JPPB representatives are participating in this study.

2. OBJECTIVES OF RESOLVE

The objectives of RESOLVE are

- To understand the effect of present air pollution sources on visibility in the R2508 region and to identify the major pollutant sources and transport routes that contribute to visibility degradation.

- To determine baseline spatial and temporal variability and trends for atmospheric visibility, aerosol characteristics, and related parameters in the study area, with special emphasis on selected locations at the military facilities.

These objectives will be met by performing a monitoring program in the study area. Intensive routine monitoring will be performed for 1 year with less intensive routine monitoring to be continued after the first year. Special studies will be performed to address issues not covered by the routine monitoring. The data collected will be analyzed to meet the above requirements.

3. BACKGROUND INFORMATION

3.1 IMPORTANCE OF VISUAL AIR QUALITY FOR OPERATIONS

The users of the R2508 airspace have a strong interest in maintaining the visual air quality of the R2508 area for several reasons:

- Test and evaluation activities conducted at NWC and Edwards AFB generally require ground-based optical data gathering over long sight paths (15 to 50 kilometers). Degraded atmospheric clarity causes increased data acquisition costs, reduced data quality, reduced flexibiity in using testing areas, reduced safety, and in severe cases, loss of test data and even loss of testing area use.

- The recent growth in use of video systems, which are more sensitive than photography to reduced-contrast, low-visibility conditions, is making operation increasingly dependent on excellent visual air quality.

- Routine training activities of all R2508 users depend on good visual air quality for efficient, safe, visual flight rules operations, and for ground-based optical monitoring of range activity (e.g., video scoring for bombing and air traffic control).

- Remote-piloted-vehicle operations, such as those conducted by NASA and NWC, are very sensitive to visual air quality due to the poor contrast sensitivity and spatial resolution of airborne video systems and the need for visual tracking by chase aircraft and ground-based observers.

- Research and development on optical (ultraviolet, visible, and infrared) sensors and guidance systems, such as that done at NWC, can be complicated by degraded visual air quality that may confound interpretation of prototype system performance. Research and development on sensors and guidance systems relying upon nonoptical techniques may also be affected by pollutants to a yet unknown degree.

3.2 R2508 GEOGRAPHY AND POLLUTANT SOURCE REGIONS

Knowledge of the geographic and source characteristics of the project area is important to understanding the monitoring approach. The southern California desert area, in the rain shadow of the Sierra Nevada and transverse mountain ranges, consists of desert valleys at elevations from 1000 to 2000 feet mean sea level (msl) separated by mountains with peaks at 6000 to 8000 feet msl. Mining, tourism, and military activities, with supporting residential and commercial activities centered in scattered small towns, characterize this generally unpopulated area. Much of the land is federally owned and managed by the Bureau of Land Management. Except for mining and tourism mentioned, the area has few local air pollution sources. However, because of their proximity, the Los Angeles urban area, and the San Joaquin agricultural and industrial areas influence visibility and air quality in the R2508 airspace (References 1 through 3). The mountains that form the western and southern borders of the desert serve to control the spread of pollutants from these areas. Polluted air masses must flow out through the passes or go over the mountain tops as they move into the desert. Land to the north and east of the military facilities is largely vacant, and not expected to be a source for polluted air masses. However, dry lakes in the desert regions are a source of wind blown dust and can contribute to localized visibility impairment under high wind conditions.

3.3 HYPOTHESES AND ASSUMPTIONS

The preliminary design of RESOLVE has been based on hypotheses about the relative importance and the likely sources of various contributors to visual impairment. These hypotheses are based on knowledge gained from prior studies and are thought to be realistic. Data obtained during RESOLVE, however, will be adequate to test these hypotheses, and changes can be made in the program design should they prove to be incorrect.

The air pollutants of importance to visibility are airborne particulates and nitrogen dioxide (NO_2). The contribution of NO_2 to visibility impairment is most important in plume optics. In well mixed layers (Reference 3), or in urban-influenced areas (References 5 through 8), the contribution of NO_2 is usually secondary to that of particulate matter. In addition, various studies in the regions downwind of Los Angeles and in the desert regions have shown NO_2 levels to be typically below the sensitivity limits of standard monitoring equipment; thus,

specialized instrumentation is necessary to get accurate estimates of NO_2 concentration. At typical desert NO_2 concentrations of under 10 ppb and with aerosol concentrations of approximately 10 $\mu g/m^3$ NO_2 will contribute less than approximately 7% of the total light extinction. An investigation of existing desert NO_2 and visibility data has been performed for RESOLVE by Sante Fe Research. This investigation shows that the contribution of NO_2 to extinction in the California desert is typically less than 5%. Thus, we have hypothesized that aerosol and not NO_2 is the dominant factor in R2508 visibility impairment, and we will not attempt to monitor NO_2 routinely at all sites. This hypothesis will be tested by performing selective high sensitivity NO_2 measurements during special short term studies. These results will be published as a technical report in the near future.

It was also hypothesized that the major sources of aerosol in the desert during periods of interest would include pollutants from the Los Angeles urban area and the San Joaquin Valley: wind blown dust from local sources; and on a very localized basis, certain industrial complexes in the desert. Minor sources of aerosol are assumed to include local urban areas and local transportation. It has been clearly shown by Smith et al (Reference 2) that both the Los Angeles Basin and the San Joaquin Valley vent into the desert during the summer and impact both the ozone concentration and visibility in the desert. The sampling network is designed to test these transport hypotheses as well as to detect the contribution of desert sources.

One assumption in designing the program is that the data of most interest are those from days of average visibility to days of highly impaired visibility. Sufficient data will be obtained to determine the baseline visibility within the region and to obtain a frequency distribution for visibility degradation. However, the extinction budgets and source attributions will be more accurate for times of impaired visibility than for times of exceedingly good visibility.

4. APPROACH

4.1 OVERVIEW

The program plan presented here is intended to be a fluid document. The plan will evolve in the early stages of the program as comments are received and suggestions are made. Later in the program, the plan will be updated periodically to take into account the findings from the RESOLVE measurements and analyses and from complementary research programs. RESOLVE will include 15 months of routine monitoring at eight sites, special studies coincident with the routine monitoring, ongoing data review and analysis, data analysis and interpretation after the 15-month monitoring period, and periodic short-term intensive studies to test hypotheses and to validate certain interpretations of the data. Routine monitoring will continue after the 15-month period at a limited number of sites. The special studies are intended to fill in holes in the data base and to test some of the assumptions made in the monitoring design. Some of these studies have been identified already while others might become necessary depending on what is learned from the monitoring. All plans for and results from RESOLVE will be available to the public for review and comment. Significant documents resulting from RESOLVE will be published by NWC in a RESOLVE report series. Technical results will also be published in the technical literature. The most detailed parts of the plan, as it now stands, concern those items funded from fiscal year 1983 and 1984 funds, especially the routine monitoring.

The routine monitoring program has been designed with the intention that

- Characteristics of pollutants from various source regions can be determined. Some sites are located to monitor sources and others are located at the receptor areas of interest.

- The spatial and temporal variations in visual air quality in the study region can be determined for the study period.

- The measurements at the receptor sites will be adequate to calculate extinction budgets (extinction as a function of composition or source of the aerosol) by multiple regression analysis.

- The data at all sites can be segregated by synoptic conditions and wind flow patterns so that the relative frequency of impact of different sources can be determined and meteorological conditions conducive to visibility impairment can be identified.

- The receptor site data, together with the source site data and meteorological data, will be adequate to do some type of source resolution analysis or receptor modeling to determine the contribution of individual source regions.

- It will be possible to use the monitoring data for case study analyses to attribute visibility impairment to specific source regions during specific episodes of low visibility.

The routine monitoring is well defined and is now operational. All eight sites include instrumentation to monitor visibility, meteorological parameters, and size segregated aerosol mass and chemistry. Continuous instruments provide hourly averaged data, and aerosol samplers provide 24-hour averages for all sites. Additional samplers and instruments of various types are being operated at selected sites. Supplemental surface and upper air meteorological data are provided by the routine range support measurements performed at Edwards AFB and NWC. The details of the RESOLVE plan, as it now stands, are presented in the subsequent sections of this document. The routine monitoring and some of the other aspects of RESOLVE are being managed by the EPA Environmental Monitoring Systems Laboratory in Las Vegas (EMSL-LV). Much of the actual work is being performed by EMSL-LV or DOD contractors or subcontractors including Lockheed Engineering and Management Services Co. (LEMSCO) in Las Vegas, the University of California, at Davis (UCD), and Global Geochemistry Corp. (GGC) in the San Fernando Valley.

The RESOLVE monitoring network has been designed to be complementary to (compatible with) other networks proposed for California by the California Air Resources Board (CARB) and to the network being implemented by the inter-organization Subregional Cooperative Electric Utility, National Park Service and EPA Study (SCENES) program. An effort will be made to coordinate with both CARB and SCENES as much as possible while still meeting the DOD objectives.

4.2 MONITORING LOCATIONS

In choosing monitoring station locations, study objectives, practical constraints, and budget were considered. A total of eight sites, listed in Table 1, were selected. Four of these—China Lake NWC, Randsburg Wash NWC, Edwards AFB, and Fort Irwin National

Training Center—are considered primary sites though they will not have identical instrumentation. The four primary, receptor-oriented sites will establish baseline visibility for the military facilities. At Edwards AFB and Fort Irwin, where the primary stations were already in operation due to a previous study, the receptor sites are representative of area-wide visibility effects, on a scale of 50 to 100 kilometers. Both stations are located on small hills that overlook the surrounding military facilities.

Two of the primary sites, China Lake and Randsburg Wash, are associated with NWC at China Lake. Nephelometer measurements have been made at these sites for several years. The town of Ridgecrest is located within a few kilometers of the China Lake test area in Indian Wells Valley; similarly, the Kerr-McGee chemical plant at Trona and part of the Randsburg Wash test area share opposite ends of Searles Valley. These two instrumented test ranges at NWC are separated by a low ridge of mountains. Because of this topographic complexity and the two significant sources, monitoring sites have been chosen for both the China Lake and Randsburg Wash test facilities. A single compromise location on the ridge separating the two areas would correctly assess the regional scale visibility but would neglect the effects of the local sources. These sites are representative of local visibility on a scale of 10 to 40 kilometers.

The other four sites are secondary sites, with three located in key passes, and one in the northern portion of the R2508 airspace. The three passes are Tehachapi, to represent airflow from San Joaquin Valley; and Soledad and Cajon Passes to represent the airflows from the Los Angeles basin. Two passes were selected to characterize the Los Angeles urban area aerosols because of the area's large size and inhomogeneous distribution of pollutant sources. In contrast, the southern part of the San Joaquin Valley contains fewer types of sources. The pass connecting Indian Wells Valley (containing China Lake) to Owens Valley to the north was not selected for a site because of ongoing studies characterizing fugitive dust from Owens Lake bed. A site near Big Pine completes the main group. The purpose of the Big Pine site is to determine visibility conditions and particulate characteristics in the northern portion of the R2508 airspace. Death Valley National Monument has been included in the study on a cooperative basis. Visibility measurements with a teleradiometer and particle measurements using a stacked filter unit are already made there as part of a National Park Service network.

4.3 INSTRUMENTATION

The monitoring equipment operating at each station is listed in Table 1. Some details of the measurements and the measurement frequencies are shown in Table 2. Additional details of the measurement techniques can be found in the Appendix. All sites have nephelometers. RESOLVE 2x4 (refers to collecton in two size ranges of a total of four simultaneous samples (1 coarse, <10 μm; 3 fine, <2.5 μm)) or Sierra dichotomous particle samplers, and meteorological sensors. The receptor sites have a second means of monitoring visibility, i.e., teleradiometer and/or camera. At Edwards and China Lake, a second nephelometer will be switched between heated and ambient temperature inlets to determine the effects of water in the aerosol. These systems have been funded by WOGA in cooperation with RESOLVE, and they will be operated for at least 6 months. Continuous solar radiation measurements and daily (work days) upper air soundings are also made at these two sites. At the secondary sites, photographs will be taken whenever the sites are visited by a techician (approximately twice a week). The location of the four UCD Rotating Universal Multistage (DRUM) samplers may be varied occasionally, but typically two will be at receptor sites and two will be at source sites. At the beginning of this study, DRUM samplers were placed at Soledad, Tehachapi, and Edwards.

TABLE 1. Routine Monitoring Stations and Equipment.

Equipment	Monitoring stations								
	Edwards AFB	China Lake NWC	Randsburg Wash NWC	Fort Irwin	Big Pine	Tehachapi Pass	Soledad Pass	Cajon Pass	Total
Nephelometer	1	1	1	1	1	1	1	1	8
Heated nephelometer	1[a]	1[a]							
Continuous teleradiometer	2	1		3					6
Camera	2	1	1	3					7
RESOLVE 2x4 particle sampler[b]	1	1	1	1		1	1	1	7
Dichotomous sampler		1			1				2
DRUM[c] particle sampler	1	1[d]				1	1		4
Wind speed, wind direction, temperature	1	1	1	1	1	1	1	1	8
Dewpoint	1	1	1	1					4
Relative humidity solar radiation	1[e]	1[e]							
Satellite data system	1	1	1	1		1	1	1	7
Memodyne™ data system	1	1	1	1					4
Strip chart recorders					1				1
Radiosonde (upper air wind speed, wind direction, temperature, and RH)	1[e]	1[e]							

[a] To be switched automatically between heated and ambient temperature inlets. These have been funded and provided to the study by the Western Oil and Gas Association (WOGA).

[b] 2x4 refers to collection in two size ranges of a total of four simultaneous samples (1 coarse, <10 μm; 3 fine, <2.5 μm).

[c] Multistage rotating DRUM impactor—described in the Appendix.

[d] To be moved between sites during the summer intensive study.

[e] Not co-located with monitoring site. Operated by range personnel.

TABLE 2. Routine Monitoring Instrumentation.

Instrument	Frequency	Parameters measured
Nephelometer or nephelometer between heated and ambient temperature inlets.	Continuous	Light scattering or light scattering by "wet" and "dry" particles.
Teleradiometer with natural target.	Continuous during daylight hour.	Total light extinction over a long path (20 to 60 kilometers) to determine homogeneity.
Camera	3 photos per day.	Documents sky and target conditions, provides visual record of visibility, records occurrences of plumes and layered haze.
RESOLVE 2x4[a] particle sampler.	Daily 24-hour samples.	Gravimetric mass for all samples; concentrations of elemental constituents with atomic mass greater than sodium. Carbon, optical absorption, and ion chromatographic analysis.
DRUM particle sampler with coated Mylar substrate (described in the Appendix).	Continuous, with filter changed every 2 weeks	Concentrations for elemental constituents with atomic mass greater than sodium in up to eight size ranges with up to 2-hour time resolution.
Meteorological sensors	Continuous	Wind speed, wind direction, temperature, relative humidity.
Pyranometer	Continuous	Solar radiation—total insolation.
Radiosonde	Weekdays in early morning at Edwards AFB and NWC. Additional launches in support of tests.	Upper air wind speed, wind direction, temperature, relative humidity.
Dichotomous samplers	24 hour samples each 6 days.	Mass, elemental composition by XRF.

[a] 2x4 refers to collection in two size ranges of a total of four simultaneous samples (1 coarse, <10 μm; 3 fine, <2.5 μm).

The fourth one will be used for special studies until the fall of 1984. State-of-the-art satellite telemetry systems are used to process the continuous monitoring data at each site to hourly averages and standard deviations that are transmitted twice daily through the National Environmental Satellite Service facilities to EMSL-LV.

4.4 OPERATION

Operation of the stations on a partial basis was started in August 1983. The stations became fully operational in April 1984 and will continue operation through April 1985. After that, operation of the stations will continue for at least 3 more months, but at a reduced level of effort, with emphasis on maintaining reasonable data recovery at the primary stations. The primary stations are expected to continue operating indefinitely. The secondary stations will be removed when they are no longer needed.

Except as indicated below, the EMSL-LV support contractor, LEMSCO, is responsible for the routine operation of the monitoring network. This operation includes equipment and particle sampler servicing, calibrations, maintenance, repairs, data processing, quality control, and regular reporting. UCD prepares the filters for elemental and mass analysis and will perform particle sample analyses. GGC prepares the quartz filters for total and organic carbon analyses. The Big Pine site is operated by the Inyo County Air Pollution Control District, with data processing for this site arranged by NWC. The data recovery target is 90%, computed for each instrument on a quarterly basis.

The LEMSCO staff for the first year of routine operation is listed in Table 3. All personnel except for the field operators are located in Las Vegas. The full-time field operator will be responsible for routine servicing and maintenance of the five southernmost stations. A part-time operator will take care of NWC China Lake and Randsburg Wash stations.

After April 1985 the total number of personnel assigned to the project will decrease. The part-time station operator support for the NWC China Lake and Randsburg Wash stations will end. Data processing and electronics technical support will also be decreased slightly as the emphasis shifts to keeping the network operational to augment special studies. However, priority will be placed on maintaining reasonable data recovery at the primary stations.

TABLE 3. Staff for Routine Network Operation.

Category	Number
Project Leader	1.0
Field operators	1.5
Electronics technician	1.0
Data processors	2.0
Supervisor	0.5
Manager	0.2
Total	6.2

Milestones through April 1985 are listed in Table 4.

The chemical analyses being performed on the 2x4 particle samples are described in Table 5. Gravimetric mass is determined for all but the quartz (carbon) filters. Analyses being performed on the DRUM samples and the methods for selecting 35 days for which the optional

TABLE 4. Tentative Milestones.

Monitoring stations deployed (without 2x4 and DRUM samplers) and reporting data	3 August 1983
RESOLVE draft Standard Operating Procedures completed	August 1983
Contractual arrangements for external quality assurance through Environmental Monitoring Systems Laboratory-Research Triangle Park and Research Triangle Institute/Rockwell International complete	10 August 1983
Sucontracts for preliminary data analysis and heated nephelometer scattering measurements in place	28 Sept. 1983
First set of station audits completed	28 Sept. 1983
EMSL-LV provides first processed data to NWC—it is provided monthly thereafter	November 1983
NWC reviews initial 3 months of operation of sites	November 1983
RESOLVE final Standard Operating Procedures completed	December 1983
RESOLVE draft Quality Assurance Manual completed	January 1984
DRUM sampler deployment completed	February 1984
2x4 comparison testing in Las Vegas completed	March 1984
2x4 sampler deployment completed	April 1984
Second set of station audits completed	April 1984
SCENES particle sampler comparison	May and June 1984
Detailed data interpretation begins	June 1984
RESOLVE final Quality Assurance Manual complete	June 1984
System audit, Las Vegas and UCD complete	July 1984
Heated nephelometer installation complete	July 1984
Special study period—mobile van	July and Aug. 1984
Third set of station audits complete	September 1984
Fourth set of station audits complete	December 1984
Fifth set of station audits complete	April 1985
Routine monitoring ends	April 1985

TABLE 5. 2x4 Sampler Filter Analyses.

Filter number	Size of particles on filter, μm	Gravimetric mass	PIXE,[a] OAT[b]	Carbon[c]	Quality control and special studies
China Lake NWC, Edwards AFB, Fort Irwin					
1	>10	All filters	Every third filter (day) plus 35 additional filters[d]		
2	>2.5	All filters	Every third filter (day) plus 35 additional filters[d]		
3	>2.5			Every third filter (day) plus 35 additional filters[d]	
4	>2.5	All filters			Selected filters
Tehachapi, Soledad Canyon, Cajon Pass, Randsburg Wash					
1	>10	All filters	75 filters[d]		
2	>2.5	All filters	75 filters[d]		
3	>2.5			75 filters[d]	
4	>2.5	All filters			Selected filters

[a] PIXE—Elemental analysis by Proton Induced X-Ray Emission Technique.
[b] OAT—Light absorption and elemental carbon by Optical Absorption Technique.
[c] Organic, elemental, and total.
[d] To be selected later based on the results of the routine analyses.

analyses are to be performed are discussed in Section 4.5. The samples from the Big Pine and China Lake dichotomous samplers will be weighed and analyzed by X-ray fluorescence (XRF) by CARB.

4.5 SELECTION OF DAYS FOR ADDITIONAL SAMPLE ANALYSIS

The routinely collected data from all sites will be used to isolate periods of degraded visibility and high particle concentrations that merit additional analysis. Periods of lowest visibility will be investigated at all receptor sites. Episodes of elevated particle concentrations at source-related sites will be analyzed for source characterization purposes. In order to determine baseline particle concentrations at the five sites where routine analysis is not planned, some analyses will also be done of the lowest particle concentrations at these sites.

Thirty-five additional 2x4 sample sets will be analyzed by Proton Induced X-ray Emission (PIXE)(total and fine filters), Optical Absorption Technique (OAT)(fine filter), and carbon

analysis (fine filter) for each of three receptor sites (Edwards AFB, China Lake NWC, and Fort Irwin). Seventy-five 2x4 sample sets will be analyzed for each of the five remaining sites (Tehachapi, Soledad, and Cajon Passes, Randsburg Wash, and Big Pine). A total of 540 additional analyses will be done for DRUM samples.

Episodes of degraded visibility are expected to occur over all sites. Therefore, 20 of the 35 additional days of 2x4 analysis for Edwards AFB, China Lake NWC, and Fort Irwin are allocated to network-wide episodes. All sites in the network would be analyzed for these days. and spatial patterns of visibility reducing particles would be determined for these days. The remaining 15 additional 2x4 sample analysis days for Edwards AFB, China Lake NWC, and Fort Irwin will be used to analyze episodes specific to each site, and will be oriented toward the needs of receptor modeling for these sites. Wind fields will be used to assess transport for these days and to indicate which upwind site samples should be analyzed.

The analysis of the 75 2x4 sample days at each of the four source related sites (Soledad, Cajon, and Tehachapi Passes, and Big Pine) and at Randsburg Wash will be divided between source characterization (30 days), network-wide episodes (20 days), support of individual receptor site episodes (20 days), and determination of baseline particle concentrations (5 days). Routine analysis is not planned for any of these five sites.

At least 540 additional DRUM samples will be analyzed by PIXE for elemental composition. Additional DRUM sample analyses at the receptor sites will be used for characterization of particles for receptor modeling and Mie scattering calculations. At the source-related sites, the analyses will be used for source characterization, receptor modeling, and receptor site episode studies. Five size ranges will be analyzed in order to determine particle size distributions for Mie scattering and source characterization. The specific time periods to be analyzed will be selected to meet the needs of the application. DRUM samples can be analyzed for time periods as short as 2 hours. Hourly nephelometer measurements will be used to determine appropriate intervals to be analyzed. Using the 540 analyses available, 108 individual time periods can be analyzed in five size ranges. This allows, for example, a total of 9 days of analysis for 8-hour intervals at each of four sites. Good temporal resolution will allow the determination of diurnal patterns and aid in determining the transport of particles. These samples will be used in part to help quantify the limitations in spatial or temporal resolution of source allocations that result from the 24-hour 2x4 sampling period.

The above discussion is necessarily a tentative one. The preliminary allocation of additional sample analysis has been done to meet the project objectives. The actual ways in which additional analysis can best meet these objectives may be subject to modification during the process of data analysis.

4.6 ADDITIONAL STUDIES

In addition to the routine monitoring, several other components of RESOLVE have been defined, and several potential complementary studies have been identified. These additional elements can be divided into near-term additional studies (to September 1984), long-term studies (post September 1984), and complementary studies (outside scope of RESOLVE). The near-term studies will be funded by DOD from their 1983 and 1984 budgets or by other organizations participating in RESOLVE (such as WOGA and EPA). The long-term studies

will be necessary to complete RESOLVE but will not be funded until the 1985 fiscal year and will not be defined in detail until a later date. The complementary studies are, in general, outside the scope of RESOLVE but have a bearing on the use of the RESOLVE results or will provide data that can be of use during the analysis of the RESOLVE data. RESOLVE is a technical study but the results of RESOLVE will have political, regulatory, and economic implications. Studies that address the political, regulatory, and economic issues are considered complementary studies.

In the near term, an intensive monitoring program will take place during the summer of 1984. This monitoring study is designed to chemically and physically characterize the contributors to light extinction at the RESOLVE pass sites and at key receptor sites. The study will utilize an instrumented movable monitoring van. Measurements will be made to test many of the RESOLVE design hypotheses and to support case-study analyses. Specifically, measurements will be made to characterize extinction as a function of time of day and location caused by NO_2, coarse particles, sulfate, particulate ammonium nitrate, and water in particulates. Detailed aerosol size distribution and chemistry measurements, and gaseous O_3, hydrocarbon, and halocarbon measurements will be made to help identify the sources of polluted air masses. The surface measurements will be supplemented by airborne lidar and possibly other airborne measurements to determine the three-dimensional spatial distribution of light-scattering aerosol. These studies will be coordinated with other complementary studies being sponsored by CARB in Los Angeles and WOGA in the San Joaquin Valley.

Additional studies of historical data will soon be completed. Analyses of historical meteorological and visibility data are under way to define a synoptic classification scheme to relate various visibility scenarios to synoptic types. Analyses of the relative contribution of NO_2 to desert light scattering and of the potential limitations that might arise from the 24-hour routine sample duration are to be published in September 1984 as NWC TP 6567, *RESOLVE Monitoring Program Plan Evaluation Using Historical Data and Error Analysis*, by John Trijonis of Santa Fe Research Corp. and others for NWC's Public Works Department.

The long-term studies include the actual formulation of the extinction budgets using the data obtained, source apportionment, long-term routine monitoring, statistical analysis of routine data to determine frequency distributions and other baseline indicators, special intensive Lagrangian (episode) studies, etc. The long-term studies will be defined in more detail at a later date. The near-term monitoring has been designed, however, to provide the data necessary for the long-term analyses. Some discussion of the long-term data analysis is presented in Section 4.8.

Complementary studies address such issues as the visibility impact on DOD operations, the effectiveness of current regulations to protect visibility, the effects of future growth in the desert on pollutant formation in the desert, and the details of aerosol sources and formation mechanisms in upwind air basins. These issues are all important in determining how and how much to protect desert visibility but they are not part of the scope of the RESOLVE monitoring study.

The JPPB has initiated a complementary study to determine the impact of impaired visibility on current DOD operations. WOGA has funded studies of the air quality in the southern San Joaquin Valley and of the impact of current air quality regulations on future visibility in the desert. CARB is conducting a study of air flow in the Los Angeles basin.

4.7 QUALITY ASSURANCE

The existing EMSL-LV and LEMSCO quality assurance (QA) plan for visibility served as the basis from which the overall project QA plan was developed. This plan, as well as the QA plans of other RESOLVE investigators, will be published as part of the RESOLVE report series.

QA and quality control activities are also described in documents prepared by the various contractors responsible for monitoring, sample analysis, and data processing tasks. In addition, an external QA contractor, Rockwell International, has been selected to audit all phases of the RESOLVE program. One result of these activities is the estimate of precision and accuracy associated with each measurement.

The monitoring contractor, LEMSCO, has prepared a detailed monitoring procedures manual, including a quality control procedures section. Topics of discussion include instrument operational checks, calibrations, zero checks, and preventive maintenance; logs and other forms of documentation; personnel responsibilities; and data control and validation. LEMSCO is responsible for processing data to engineering units and providing statistical and graphic summaries of the data. Hence, they will also provide procedures that allow evaluation of data traceability and the validity of computer algorithms.

Each particle sample analysis contractor has provided a detailed analysis procedures manual, including a quality control procedures section. Included in these manuals are discussions of the following: repeat analyses, laboratory and field blanks, analysis-system calibration, filter handling and storage procedures and environment, logs and other forms of documentation, and data control and validation. Analysis contractors will process data to engineering units. The elemental and gravimetric analysis contractor, UCD, will also provide statistical and graphic summaries of the data; EPA-Las Vegas will provide summaries for the other particle analysis data. The responsible organizations will prepare procedures that allow evaluation of data traceability and the validity of computer algorithms.

Rockwell International will perform at least five field, laboratory, and overall systems audits during the RESOLVE program. They will provide a procedures document describing their methodology. The purpose of the external audit program is to provide an independent check on the adequacy of equipment, supplies, personnel, and procedures to evaluate the degree to which procedures are followed and to provide an opportunity for remedial action when problems are identified. Activities performed by Rockwell International will include sampler flow audits, calibrations, filter analysis audits, inspection of logs and other documents, review of procedures, and interviews of personnel.

Several comments have been made and questions asked about QA for the filter analysis techniques. Plans that address some of these issues are outlined below.

4.7.1 Quality Assurance for PIXE and Mass Samples

The QA and quality control procedures for the RESOLVE sample handling and analysis will be similar for that used for the EPA Visibility Investigative Experiment in the West (VIEW) program and the National Park Service (NPS) fine particle network. Detailed QA plans have been prepared by UCD for these programs and the QA plan for RESOLVE will be

a modification of the earlier plans. Extensive audits of the UCD filter handling, weighing, and PIXE analysis procedures have been conducted by Rockwell International, and the procedures and results have been found to be sound.

The UCD quality-control procedures include

- Extensive documentation including checklists, logsheets, and standard handling procedures.
- Detailed procedures for review of sample documentation.
- Daily calibration of balances (mass) and PIXE system with National Bureau of Standards (NBS) traceable standards.
- Multiple weighings of selected samples by different people.
- Field and laboratory blanks.
- Multiple analyses of the same filters or DRUM substrates.
- Cross checks of filter weights and PIXE results.
- Comparison of DRUM sample and 2x4 filter results.
- Computer scanning of results for outliers.
- Short sample residence time in the field. Turnaround time will generally be kept to under 3 weeks between initial filter weighing and final weight determination.

4.7.2 2x4 Cross-checks and Intercomparisons

The 2x4 sampler is a newly designed sampler that uses a group of previously well-tested components. As such, the sampler's performance should be predictable. The inlet systems are standard commercial items. Their size classifying characteristics at the flow rates used are well known, and the manufacturer has provided wind-tunnel test results. When delivered, there were operational and leakage problems with the samplers. An extensive refurbishment program was undertaken and final versions of the sampler were operational by March 1984. When the modifications were completed, all 2x4 samplers were run side-by-side and compared with a commercial dichotomous sampler. Mass and chemical measurements were intercompared and found to agree satisfactorily. A report on the intercomparison will be prepared by midsummer and subsequently released for public review.

An additional intercomparison test between the RESOLVE 2x4 samplers and numerous other samplers was funded by the Electric Power Research Institute (EPRI) and is being conducted by the SCENES participants.

The evaluation of the 2x4 samplers will continue in the field. At the China Lake site, the sampler will be run side-by-side with a CARB 10-micrometer inlet dichotomous sampler and the results will be intercompared.

4.7.3 DRUM Sampler Calibration and Intercomparison

Several checks of the DRUM sampler performance were performed by UCD. The samplers have been tested with various types and sizes of aerosol samples under a wide range of temperature conditions. The bounce-off and efficiency characteristics of the sampler are being determined. The sampler has been compared with a previously tested and well characterized low pressure impactor.

4.7.4 Weight Gain on Teflon Filters

The EPRI Western Regional Air Quality Study has identified a problem with weight gains of unknown origin on teflon filters. Nininger, et al (Reference 9) reported weight gains that are more or less linear with time over a 30-day period. For a 37-millimeter teflon filter, the gain amounted to about 20 + 10 μg per filter in 30 days. In the RESOLVE project, this would be equivalent to an error of less than 1 $\mu g/m^3$. Nininger, et al (Reference 9) concluded that their data could be partially corrected for the error. Since the time between weighings for the RESOLVE samples will be typically about 3 weeks and some correction can be applied, it is probable that the error in the results can be kept to less than 0.5 $\mu g/m^3$. Since the sample concentrations of interest in RESOLVE will typically be greater than 5 to 10 $\mu g/m^3$, this error should not substantially affect the RESOLVE results. Recent work by Feeney, et al (Reference 10) has helped explain the weight gain phenomenon, and evidence obtained during the intercomparison test indicates that the weight gain interference can be kept within the above limits.

4.8 DATA ANALYSIS AND INTERPRETATION

Data analysis and interpretation for the RESOLVE program can be divided into three phases: (1) analysis of existing data to define limitations and potential accuracy of the analyses that will be done using the RESOLVE data, (2) on-line analyses (while monitoring is in progress) to evaluate and classify the data obtained and to suggest potential midcourse corrections in the monitoring plan, and (3) final data analysis to satisfy the RESOLVE objectives. Some of the analyses to be performed during each phase are outlined below.

4.8.1 Preliminary Analysis of Existing Data

Existing desert data have been reviewed to assess the potential limitations in meeting the project objectives that might arise from the 24-hour sample duration to be used for the 2x4 samplers (as opposed to a shorter sample cycle). Desert NO_2 data have been reviewed to determine the average NO_2 concentrations actually measured in the desert and to assess the requirement for additional NO_2 measurements. A report on the results of these studies is in preparation. The conclusions and recommendations are consistent with the current monitoring plans. Existing meteorological and nephelometer data are being reviewed to determine the frequency of substantial visibility impairment at Edwards AFB and NWC, China Lake, and to determine the probable sources as a function of time of day and season. These analyses will be used to help define special studies that might be useful. Existing data and previous studies will be reviewed to help assess the best approaches to use for regression analyses and receptor modeling and to help assess the potential limitations of these types of analyses.

4.8.2 On-line Data Analyses

Some of the types of analyses that will be performed while the monitoring is in process are listed below.

- Regress and scatter plot fine particle mass against nephelometry scattering data. Multiple regress fine particle chemical species against particle scattering. Compare results to literature values.

- Compare simultaneous data from different particulate samplers with respect to particle mass and chemical composition.

- Examine the chemical composition data from the particulate monitors to check that the samples are large enough (i.e., the sampling periods and/or flow rates are adequate).

- Regress particle absorption measurements versus fine elemental carbon concentrations. Multiply regress particle absorption versus fine elemental carbon, coarse elemental carbon, and soil dust estimates. Compare results to literature values.

- Plot and regress (nonlinearly) ambient-minus-heated nephelometer data versus relative humidity and aerosol electrolyte concentrations. Compare results to thermodynamic theory.

- Perform rudimentary mass balances for fine and coarse particles by comparing total mass to sum of chemical species.

- Compare detailed size distributions among the drum samples, optical particle counter, and/or electrical aerosol analyzer (if available).

- Perform intersite comparison of wind data.

- Classify sampling days by synoptic situation and by wind flow patterns.

- Perform case study analyses of selected episode periods. Integrate the meteorological and chemical data to determine source regions for contributors to extinction at each receptor.

4.8.3 Analyses to Meet the RESOLVE Objectives

This section describes some types of data analyses that can be used to satisfy the objectives of the RESOLVE program. Experience has shown that data collected in such a program do not always lend themselves equally to every anticipated method of data analysis. The methodology below should be thought of as the opening moves of an evolving strategy. Factors, unknown at present, are expected to influence the final methods used and their degree of success.

RESOLVE study objectives include the determination of source-effect relationships and baseline documentation. Figure 2 is a schematic illustrating the types of data to be collected in RESOLVE and some methods by which the data can be analyzed to satisfy the study objectives. This figure will serve as the framework for the following discussion. The techniques

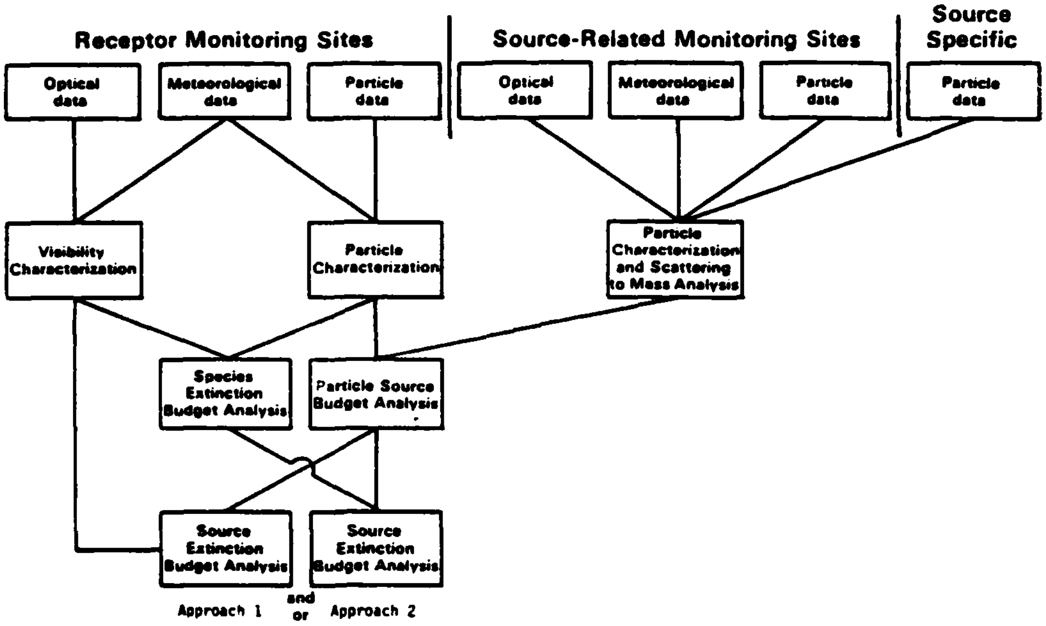

FIGURE 2. Types of Data for the RESOLVE Data Analysis.

discussed here are statistical approaches that use large portions of the data base. Additional analyses of case studies will also be performed to put the statistical results in perspective.

The first row of boxes in Figure 2 represents types of data, classified as meteorological, optical, and particle, and collected from three categories of data sources: receptor monitoring sites, source-related monitoring sites, and source-specific studies. The first two data sources include all measurements at the RESOLVE monitoring sites plus National Weather Service and other available meteorological data. Data in these two categories are documented as a function of time. The source-specific category consists of particulate emission profiles for sources of primary particles. Particle characteristics (size and chemical composition) will be determined from the literature for various sources (e.g., vehicular exhaust, earth crustal material, vegetative burning, fuel oil combustion, and mineral processing). Total source emission rates are not required for the analyses outlined below.

The baseline documentation objective is met in the second row of the diagram upon completion of the two steps labeled "Visibility Characterization" and "Particle Characterization." Visibility and particle data from the receptor sites (all within the R2508 air space) will be processed to engineering units and displayed using a variety of statistical and graphic techniques (mean and standard deviations, time plots, frequency distributions, maps, association of photographs with numeric data, etc.). These displays can be used for data collected over the duration of the study or subsets of the data, segregated by time (seasons, weekday/weekend, diurnal, etc.), and by meteorological conditions (wind speed/direction, stability, relative humidity, cloud cover, back trajectory characteristics, etc.). Some of these displays of segregated data may suggest the relative importance to visibility/particles of various atmospheric processes and sources. Comparison of similar parameters (nephelometer/telephotometer visibility, DRUM 2x4 particulate parameters, optical

absorption/thermal analysis elemental carbon) will also be conducted. Furthermore, there will be statistical studies of meteorological influences (meteorological classification schemes. wind/pollution roses, trajectory analyses, and identification of episodes). Many of the baseline documentation studies (e.g., maps, trajectory analyses, and intersampler comparisons) will also make some use of aerometric data from the source-related monitoring sites.

The box labeled "Particle Characterization and Scattering to Mass Analysis" has two purposes. Primarily, it represents efforts by the RESOLVE program to associate major source areas (Los Angeles urban area and San Joaquin Valley) and major source types (earth crustal, motor vehicles, fuel combustion, mineral processing, vegetative burning, etc.) with unique particle size-resolved chemical characteristics. A unique elemental tracer for a source area or source type is the most desirable type of characteristic because of the ease with which it can be employed in later analysis steps. It is not expected, however, that single tracer elements will be available for most of the source categories thought to impact the RESOLVE study area. Distinctive ratios of two or more elements, or, where possible, complete size-segregated chemistry, of particles from a source category could then be used. Advanced statistical techniques are available for distinguishing individual source contributions in the case of multiple sources and multiple characteristics (various elements and various sizes). Statistical methods are also available for assessing errors and uncertainties.

Problems arise when two source categories emit very similar particles: it may not be feasible to distinguish among various types of dust sources (such as paved roads, unpaved roads, agriculture, and construction) or various types of fuel combustion sources (e.g., residential, industrial, and utility). Problems also occur when the size-resolved chemistry of particulate emissions from a source changes with time in an unknown or unpredictable way (e.g., mineral processing may involve the use of various ores). In a similar way, secondary particles resulting from atmospheric transformation of gaseous pollutants (sulfates, nitrates, organic species) may be a problem because the precursor emissions are usually not uniquely "traceable," and because particle formation and growth depends in a complex way on many (usually unknown) factors. The source-related sites, however, should provide a detailed characterization of secondary particles and co-transported tracers from the two major source areas. Of interest in this regard is the temporal stability of the secondary aerosol size distribution, the characteristics of associated primary particles, and the temporal stability of the ratio between primary and secondary species. If the mix of primary to secondary particles for a source area is reasonably stable, then the primary particles can be used as a tracer for the secondary particles. Even if this is not generally true, it may still be true when data are partitioned by meteorological or other factors. It may also be possible to use the size distribution of the secondary particles as a tracer, if it is unique to the source area.

The secondary purpose represented by the same step (as shown in the diagram) is a calculation of the scattering/mass ratio for each source area. It may be possible to track and intercompare the scattering efficiencies for particles from the two source areas as a function of time and meteorological conditions.

The box labeled "Species Extinction Budget Analysis" represents the combining of optical and particle data at the receptor sites, with the object of determining the relative importance of each particulate species to visibility reduction. Generally, there are two approaches used to determine extinction budgets, a deterministic approach using Mie theory, and a statistical approach typically involving multiple linear regression.

The optical extinction associated with particles can be calculated using Mie theory if the particle characteristics are well documented. The size-distribution, shape, density, and refractive index of the particles are needed for such a calculation. Often, much of this information is either unavailable or available with insufficient detail, so that Mie theory must be used with unproven assumptions. Mie calculations will be run for sites with DRUM particle samples. The Mie calculated total extinction will be compared to the actual total extinction as a measure of confidence in the Mie approach. The Mie theory results will also be compared with the corresponding statistical results.

The statistical (regression) approach fits data to an equation of the form,

$$Y = A_0 + A_1X_1 + A_2X_2 \ldots + A_nX_n,$$

where

Y = the dependent variable

X_i = the independent variables

A_i = the regression coefficients

For this application, the dependent variable would be the *scattering* coefficient from the nephelometer or the *extinction* coefficient from the teleradiometer, and the independent variables would be the concentrations of particle chemical species (e.g., sulfates, organics, and dust particles). The regression coefficient corresponding to each particle species can be interpreted as the scattering or extinction efficiency of that species. The contribution of each particle species to total scattering or extinction is the product of the regression coefficient and the species concentration. This analysis allows the construction of a budget allocating scattering or extinction among the particle species. The significance of each term in the budget and the overall significance of the linear regression model can be evaluated using various statistical tests.

In the above analysis, the contribution of Rayleigh scatter and gaseous NO_2 to visibility reduction is handled separately. It is usually calculated by applying known physical constants to air density and measured NO_2 concentrations. If the regression model is applied to nephelometry data, so that it represents a *scattering* budget, then particle absorption must also be handled separately. Elemental carbon aerosol usually accounts for nearly all of particle light absorption. The absorption calculation can be handled either by using published values for the absorption efficiency of elemental carbon or by performing regressions relating absorption measurements to elemental carbon and other aerosol species.

The "Particle Source Budget Analysis" box in Figure 2 represents a process of apportioning the particles at the receptor sites to contributions from source areas and source categories. This process, called receptor modeling, builds on the Particle Characterization and Scattering to Mass Analysis and was partly discussed earlier under that topic. The size-resolved composition for each receptor site particle sample (or average of samples) is attributed to a combination of size-resolved characteristics associated with the sources. The complexity of this process will depend on the uniqueness of particle characteristics as determined in Particle Characterization and Scattering to Mass Analysis. Sources having unique conservative tracers are easily identified in receptor samples. Preliminary efforts to attribute particle samples to sources may

be unsuccessful in identifying all significant contributions. This lack of success could result from problems such as the selection of a nonconservative tracer, uncertainties in the data, or impacts of sources not originally anticipated. Thus, these two analysis steps will likely be used in an iterative fashion and may require the gathering of additional source-specific "Particle Data."

The last two steps shown in Figure 2 are both labeled "Source Extinction Budget Analysis." Two steps are shown so that two alternative paths to the result can be clearly distinguished. The first approach employs either Mie theory or multiple linear regression to relate particulate sources *directly* to their visibility impact at receptor sites. Both of these techniques would be used in a fashion very similar to that described in the Species Extinction Budget Analysis. For Mie theory, the difference is that separate Mie calculations would be performed for the *individual source* areas or categories as developed in the Particle Source Budget Analysis. As before, physical characteristics of the particles associated with each source must be known or assumed to make Mie calculations. This assumption may restrict the Mie technique to sample periods and sites characterized with DRUM particle analysis data. The use of multiple linear regression is the same as described for Species Extinction Budget Analysis, except that the independent variables are the concentrations of particles associated with the various *individual* source categories. Thus, the product of each regression coefficient and corresponding source concentration is the extinction attributed to that source.

The alternative process (approach 2) involves an additional step. Working with the results of the Species Extinction Budget Analysis, whether from Mie theory or multiple linear regression calculations, the extinction from each chemical species is apportioned among particulate source categories. The Particle Source Budget Analysis results provide the means to allocate each species among the source categories. This analysis is the basis for determining the proper allocation of species extinction among the sources.

The analysis plan discussed above provides several paths for obtaining a source extinction budget that can satisfy the RESOLVE objective to identify the effect of present sources on visibility. It is not unlikely that if more than one method should succeed, the results will vary somewhat. If the results are significantly different, an effort will be undertaken to explain the differences and arrive at the most supportable conclusions.

5. MANAGEMENT PLAN

The JPPB has selected NWC at China Lake to coordinate RESOLVE. Figure 3 is an organization chart that indicates the roles of various participants.

The organization in Figure 3 assumes that

- T. Dodson of NWC is responsible for overall direction of the project. He will represent the JPPB.

- R. Kelso of NWC is responsible for day-to-day project management and implementation of policy decisions.

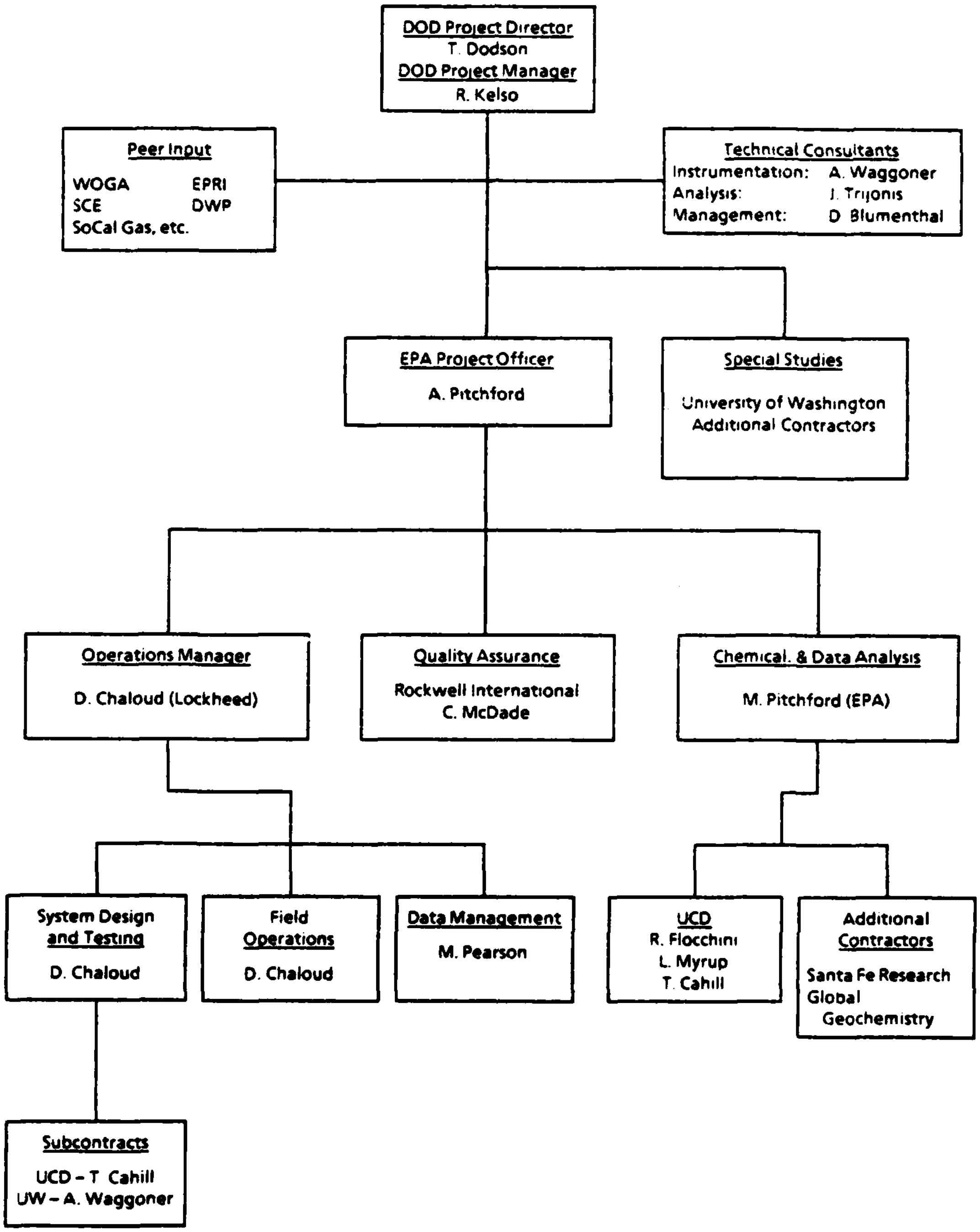

FIGURE 3. RESOLVE Project Organization.

- Dodson and Kelso will be aided by A. Waggoner, J. Trijonis (Santa Fe Research), and D. Blumenthal (Sonoma Technology), A. and M. Pitchford (EPA), and R. Flocchini (UCD) who will provide technical advice and will help review and sort out input from other interested parties.

- Input from interested parties will be sought and considered. Such input will go directly to Dodson and Kelso through a mechanism of review meetings.

- The bulk of the work will be coordinated by EPA under the direction of A. Pitchford. Some "special studies" may be performed under direct contract to DOD. Kelso and Dodson, with the aid of technical consultants, will be responsible for integrating into the program the results of any special studies funded directly by DOD.

- Routine field operations and data processing will be contracted through Lockheed and coordinated by D. Chaloud. Assistance will be provided by M. Pearson.

- Data analysis will be coordinated by M. Pitchford. Routine mass, PIXE, and OAT analyses will be coordinated by Flocchini.

- Some special studies may be funded through EPA or Lockheed.

- All operations and data analysis plans must be approved by Dodson or Kelso.

Some elements are not yet covered by the organization chart. The special studies will have to be included when they are defined in more detail, and provisions eventually will have to be made for coordinating the data interpretation and for generating a final report from the project.

Appendix

INSTRUMENTATION DETAILS

Several types of instruments will be employed to characterize various aspects of visibility. Teleradiometers will be used with natural targets. Inherent contrasts for these targets (expected to be rock-colored) will be developed using the techniques described in Chaloud and Pierett (Reference 11). Teleradiometers provide a measure of apparent contrast, C_r, of a distant target against its background (typically the sky). This, along with the distance to the target, r, and its inherent contrast, C_o, can be used to estimate extinction coefficient, b_{ext} by

$$b_{ext} = -1/r \ln C_r/C_o \qquad (1)$$

Visibility is often expressed in terms of visual range, the greatest distance at which a dark object is visible. Visual range, VR, is related to extinction coefficient by

$$VR = 3.912/b_{ext} \qquad (2)$$

Integrating nephelometers make a point measurement of scattering coefficient, b_{scat}, which is a portion of the extinction coefficient.

$$b_{ext} = b_{scat} + b_{abs}, \qquad (3)$$

where b_{abs} is the absorption coefficient. If the absorption coefficient is assumed to be small compared to the scattering coefficient, then b_{scat} can replace b_{ext} in Equation 2 in order to calculate VR. Nephelometers can be operated with ambient temperature inlets or can be switched between heated and ambient temperature inlets to measure scattering coefficient for "dry" and "wet" particles. In either case, a clean air system can be used to provide particle-free reference air to check for electronic drift. A more complete discussion of these two measurement techniques is available elsewhere (References 12 through 16).

The methods described above rely on various assumptions such as cloudless skies, or homogenous air pollution. Color slides were selected to provide an overall qualitative means to document area-wide visibility. Photographs will be useful for recording cloud conditions, occurrences of layered haze and plumes, and a history of various visual conditions at one location. Three color slide transparencies of each teleradiometer target will be recorded daily by automatic camera systems at about 0900, 1200, and 1500 local time. Although the photographs are intended only as a qualitative record of visual conditions, stringent operational controls will be maintained.

Two types of particle samplers will be used routinely. The first type, the RESOLVE 2x4 sampler provides a total of four filters in two size ranges: one filter for particles less than 10 micrometers and three filters for particles less than 2.5 micrometers. Filter substrates can be chosen to be compatible with a variety of analysis techniques. The RESOLVE 2x4 sampler will

be specially fabricated for this study. The sampler's characteristics include collection efficiency curves similar to those of a virtual impactor; capability to operate unattended for up to nine, consecutive, 24-hour sample periods; use of a variety of filter media; filters mounted in a cassette to minimize handling; and size-segregating characteristics that are insensitive to winds. Twenty-four-hour samples will be collected on a daily basis with this sampler. Results of preliminary analyses of daily particle samples collected at Edwards AFB indicate that this frequency of sampling is appropriate for the variability in the data. Less frequent or longer samples tend to smooth the results considerably.

The second type of sampler is the University of California, Davis, Rotating Universal Multistage (DRUM) sampler (Figure A-1). It consists of a seven-stage, Lundgren-type rotating drum sampler preceding either a Florida-State-style circular streaker or an eighth Lundgren impactor stage. Impactor stages will be capable of low pressure operating characteristics similar to a low pressure impactor by the insertion of a critical orifice between stages 4 and 5 or in place of any impactor jet. Drum rotation speed is adjustable. However, using 1 rotation per 2-week period allows analytical resolution on the order of 1 to 2 hours. By scanning appropriate portions of the deposits, a time average of any duration (from a few hours up to the entire sample) can be measured. Deposits from different stages can be aligned side-by-side for scanning, allowing averages over size also. The philosophy of the DRUM sampler is to collect samples that are capable of yielding information with a high level of detail, but allowing a decision on the extent of the analysis to be postponed until after sample collection. This decision provides a very cost effective approach to ambient particle sampling. Three DRUM samplers will be used in the study; at least one will be operated routinely at a primary site.

The techniques anticipated for routine analysis of the particle samples include Particle Induced X-ray Emissions (PIXE) for both DRUM and 2x4 samples and Optical Absorption Technique (OAT), and weighing to determine gravimetric mass, for the 2x4 samples only.

PIXE analysis provides a quantitative measurement of elements with atomic numbers greater than or equal to that of sodium. An alpha beam from the cyclotron located at the University of California, Davis, is used to excite X rays in the particulate sample. By evaluating the energy and total number of these X rays, the elements are identified and their concentrations are computed (Reference 17). The analytical system has participated in various interlaboratory comparisons, achieving mean absolute accuracy of +6% for elements heavier than magnesium (Reference 18). DAT correlates with the mass of soot carbon. A Cahn 25 micro-balance is used to analyze samples gravimetrically. Careful attention is given to neutralization of electrostatic charge and balance equilibrium before values are recorded (Reference 19).

The elemental concentrations measured by PIXE are used to compute the assumed oxide states for particle constituents including soil, sulfate, salt, lead plus bromine, and other elements. Elemental sulfur and chlorine are used to compute sulfate and salt, respectively. The lead plus bromine concentration serves as an indicator of automotive exhaust.

Meteorological sensors for wind, temperature, and relative humidity complete the list of routine monitoring equipment.

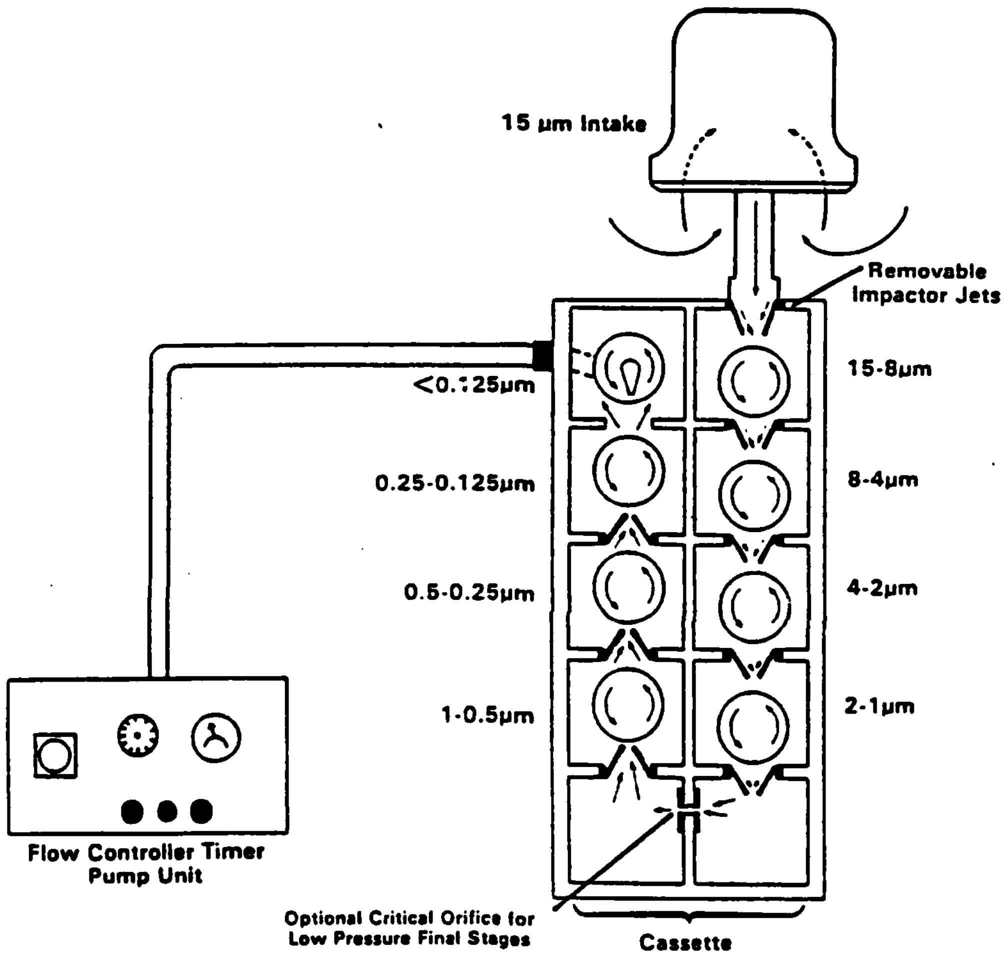

FIGURE A-1. The University of California, Davis, Rotating Universal Multistage (DRUM) Sampler.

REFERENCES

1. D. D. Reible, J. R. Ouimette, and F. H. Shair. "Atmospheric Transport of Visibility Degrading Pollutants into the California Mojave Desert," *Atmos. Environ.* Vol. 16 (1982), pp. 599-613.

2. T. B. Smith, D. E. Lehrman, F. H. Shair, R. S. Lopuck, and T. D. Weeks. *The Impact of Transport from the South Coast Air Basin on Ozone Levels in the Southeast Desert Air Basin—Volume 2 - Results and Discussion*. Prepared for the California Air Resources Board, Sacramento, Calif., April 1983.

3. J. Trijonis, "Visibility in California," *J. Air Poll. Contr. Assn.* Vol. 32, No. 2 (1982), pp. 165-69.

4. A. P. Waggoner, R. E. Weiss, N. C. Ahlquist, D. S. Covert, S. Will, and R. J. Charlson. "Optical Characteristics of Atmospheric Aerosols," *Atmos. Environ.* Vol. 15 (1981), p. 1891.

5. G. T. Wolff, M. A. Ferman, N. A. Kelley, D. P. Stroup, and M. S. Ruthkosky. "The Relationships Between the Chemical Composition of Fine Particles and Visibility in Detroit Metropolitan Area," *J. of Air Poll. Contr. Assn.* Vol. 32 (1982), p. 1216.

6. T. G. Dzubay, R. K. Stevens, C. W. Lewis, D. H. Hern, W. J. Courtney, J. W. Tesch, and M. A. Mason. "Visibility and Aerosol Composition in Houston, Texas," *Environ. Sci. Technol.* Vol. 16 (1982), p. 514.

7. R. J. Charlson, "Atmospheric Visibility Related to Aerosol Mass Concentration," *Environ. Sci. Technol.* Vol. 3 (1969), p. 913.

8. P. J. Groblicki, G. T. Wolff, and R. J. Countess. "Visibility-Reducing Species in the Denver 'Brown Cloud'-1. Relationships Between Extinction and Chemical Composition" *Atmos. Environ.* Vol. 15 (1981), p. 2473.

9. R. C. Nininger, I. H. Tombach, and D. V. Allard. "Aerosol Measurements for the W-RAQS Visibility Study - Investigation of Sources of Error." presented at the APCA Annual Meeting, 1983. (Paper No. 83-10P.7, 1983.)

10. P. Feeney, T. Cahill, J. Olivera, and R. Guidara. "Gravimetric Determination of Mass on Lightly Loaded Membrane Filters," *J. Air Poll. Contr. Assn.* Vol. 34 (1984), p. 376.

11. Environmental Protection Agency. *Visibility in the California Desert*, by D. J. Chaloud and S. L. Pierett. 1983. (Unpublished report.)

12. Environmental Protection Agency. *Protecting Visibility: An EPA Report to Congress*, 1979. (EPA-450/5-79-008).

13. Environmental Protection Agency. *Interim Guidance for Visibility Monitoring*, 1980. (EPA-450/2-80-082).

14. W. Malm, "Considerations in the Measurement of Visibility," *J. Air Poll. Contr. Assn.* Vol. 29, (1979) p. 1042.

15. W. C. Malm, M. Pitchford, and A. Pitchford. "Site Specific Factors Influencing the Visual Range Calculated from Teleradiometer Measurements." *Atmos. Environ.* Vol. 16 (1982), p. 2323.

16. W. E. K. Middleton, *Vision Through the Atmosphere*. Toronto, Canada, University of Toronto Press, 1952.

17. J. Harrison and R. A. Eldred, "Data Acquisition and Reduction for Elemental Analysis of Aerosol Samples," *Advances in X-Ray Anal.* Vol. 17, (1973) p. 560.

18. Environmental Protection Agency. *Intercomparison of Samplers Used in the Determination of Aerosol Composition*, by D. C. Camp, A. L. Van Lehn, and B. W. Loo. 1978 (EPA 600/7-78-118).

19. D. R. Engelbrecht, T. A. Cahill, and P. J. Feeney. "Electrostatic Effects on Gravimetric Analysis of Membrane Filters," *J. Air Poll. Contr. Assn.* Vol. 30 (1981), pp. 391-92.

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